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# The Garden Symphylid,

## *Scutigerella immaculata* Newport

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# THE GARDEN SYMPHYLID,

## *Scutigerella immaculata* Newport[1]

G. A. FILINGER

## INTRODUCTION

The garden symphylid, *Scutigerella immaculata* Newport, was discovered and described by Newport in 1844. Since that time it has held the interest of many systematic zoologists, because it belongs to a group, the Symphyla, which have some very interesting primitive characters. Some taxonomists believe that this group forms the link between centipedes and insects; whereas others place the group between the millipedes and centipedes. A new interest, however, was aroused when Woodworth, in 1905, reported serious injury to asparagus in California due to Symphylids. The economic importance was still further demonstrated when Davis, in 1912, reported damage to ornamental plants in greenhouses in Illinois. The writer was impressed with the seriousness of this pest when he visited the vegetable growing sections in southwestern Ohio in 1926.[2] The garden symphylid was found to be a serious problem in vegetable greenhouses and in truck gardens around the greenhouses, as well as in greenhouses where ornamental plants were grown. Many of the greenhouse men were on the point of bankruptcy because a paying crop had not been grown for a number of years, due to the ravages of this pest. The writer immediately started investigation of this problem and some of the results of this study are here presented.

## SYNONYMY

*Scutigerella immaculata* Newport

1844. *Scolopendrella immaculata* Newport. Trans. Linn Soc. London, **19**, p. 374.

1847. *Scolopendrella immaculata* Gervais. Hist. Nat. d. Ins. Apt. **10**, p. 303.

1851. *Scolopendrella immaculata* Menge. Neuste Schr. d. Naturf. Ges. Danzig IV. Heft. **4**, p. 14.

1873. *Scolopendrella americana* Packard. Proc. Boston Soc. Nat. History, p. 111.

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[1]Submitted in partial fulfillment of the requirements for the degree of Doctor of Philosophy at the Ohio State University.

[2]Acknowledgments.—The writer wishes to acknowledge his indebtedness to Professor J. S. Houser under whose guidance the work discussed in this paper was done, as well as to Prof. Raymond Osburn and to Dr. Herbert Osborn for criticisms and much valuable help; also to Mr. H. M. Prager for his help in preparation of many of the photographs used in illustrating the paper. The writer also wishes to thank the following growers who gave space in their greenhouses and helped in carrying out the experiments: Mr. George Ehrhardt of Sidney, Ohio; Mr. Fred Meier of Mt. Healthy, Ohio; Mr. R. W. Sollberger, Mr. Fred Hackemeyer, Mr. Fred Buns, and Mr. F. Winkleman of Cincinnati, Ohio.

1876. *Scolopendrella immaculata* Rosicky. Archiv d. Naturw. Landesdurchforsch. v. Bohmen (Prag) 3, p. 17-18.

1881. *Scutigerella immaculata* Ryder. Proc. Nat. Acad. Sci. Phil., p. 85.

1881. *Scolopendrella immaculata* Packard. Amer. Naturalist, 15, p. 698.

1882. *Scolopendrella immaculata* var. *anophthalama* Joseph, Berliner entomol. Zeitschr. 26.

1882. *Scolopendrella immaculata* Karlinski. Sprawozd. Komisyi fizyogr 17, p. 233.

1884. *Scutigerella immaculata* Latzel. Die Myriopoden der Oestereichisch Ungarischen Monarchie 2, p. 1-18.

1903. *Scutigerella immaculata* Hansen. Quart. Jour. Micros. Sci. (London) N. S. 185, 7, Part 1, pp. 1-101.

1905. *Scutigerella californica* Woodworth. Cal. Jour. of Technology, 6, p. 38.

The common names for this creature are many. Woodworth, 1905, refers to it as a "new centipede of economic importance". Essig, in 1915, calls it the "lima bean symphylid" and, in 1921, refers to the same creature as the "garden symphylid". Wymore (1924) calls it the "garden centipede". Essig in 1926 also calls it the "garden centipede". The writer, in 1928 and again in 1931, continued the name "garden centipede". Riley, in 1929, uses the name "greenhouse centipede". The growers in Ohio refer to the pest as "the little white worm". In Indiana, the writer heard the growers refer to the creature as the "galloping dragon".

From the foregoing it would seem that it is time some common name should be adopted. Since the creature is a Symphylid and not a centipede, it would seem logical to use the former, rather than the latter, in the common name. As it is not limited to the greenhouse but is also a pest in gardens and truck fields, the writer is of the opinion that the name "Garden Symphylid", used by Essig in 1921, should be adopted as the common name.

## HISTORICAL

*Scutigerella immaculata* Newp. belongs to the class, Symphyla; whereas the centipedes are in the class, Chilopoda. Scopoli described the first species of this class, in 1763, under the name of *Scolopendra nivea,* apparently believing at that time that the animal was a true centipede of the genus *Scolopendra.*

Gervais, in 1836, described the second species of the present class Symphyla and called it *Geophilus junior.* In 1839, he changed the name to *Scolopendrella notocantha* and referred it to the family Geophilidae.

Newport found a third species and described it under the name of *Scolopendrella immaculata* in 1844. This is the form now known as *Scutigerella immaculata* Newport.

Menge in 1851 published a very excellent anatomical treatise on *Scolopendrella immaculata* Newp., which is surprisingly accurate, considering the equipment of his day. He described the head, the antennae 40-42 jointed, parapods, and cerci. He also described the digestive tract, the nerve cord, and the ovaries and oviduct (which he said opened above the anus). He said there were four Malpighian tubes instead of two, the correct number.

In 1880, Ryder raised this group to an order and called it Symphyla, because the group possesses characters of both Myrispoda and Thysanura. In 1882, he divided the group into two genera, *Scolopendrella* and *Scutigerella,* the distinguishing character being the shape of the dorsal scuta.

Packard, in 1881, classed Symphylids as insects with the Thysanura and put them in a suborder with Cinura and Collembola.

Wood-Mason, in 1883, published a very detailed description of the appendages of Symphyla. He stated that the coxal sacs were analogous to nephridia and that there were tracheae, or breathing tubes, arising at the base of the legs and forming internal arches.

Haase, in 1883, published an excellent description of the tracheal system of the Symphylids. He agreed with Menge that the tracheae are in the head and demonstrated two stigmata on the head. He showed that what Wood-Mason and Ryder interpreted as tracheae were arches of the endoskeleton.

In 1884, Latzel described the external and internal anatomy very carefully and quite accurately.

Grassi gave a very accurate and detailed description of *Scutigerella immaculata* Newp. in his paper published in 1886.

Schmidt, in 1895, agreed with Haase that the tracheae are in the head region. He interprets the parapods as rudimentary abdominal legs.

Hansen, in 1903, brought together much of the information available on Symphylids. He described in some detail peculiar sense organs on the terminal segments of the antennae of *Scutigerella.* He adds ten new species of *Scutigerella* and nine new species of *Scolopendrella.*

Woodworth, in 1905, was the first to point out the economic importance of *Scutigerella immaculata* Newp. as a pest in the truck crop sections of California. He described it as a new species under the name of *Scutigerella californica* Woodworth. He is of the opinion that Symphyla should be placed between Scolopendra and Lithobiidae. Heretofore, the Symphylids had been considered as carnivorous, feeding on microscopic organisms.

Williams, in 1907, published a paper in which he discussed the eggs, larvae, and adults. The method of locomotion, he stated, resembles Diplopods but is much more rapid. He gave a detailed description of the molting of this species.

Davis, in 1912, was the first to report *Scutigerella immaculata* Newport as damaging greenhouse crops. He stated that "fern-asparagus and smilax were injured in Illinois as early as 1908."

Bagnall, in 1913, attempted to establish from the two genera, *Scutigerella* and *Scolopendrella,* the subfamilies, Scutigerellinae and Scolopendrellinae. He added five new species to this group.

In his book, *Injurious and Beneficial Insects,* Essig, in 1915, discusses *Scutigerella californica* as the "lima bean symphylid". He described the nature of the injury and illustrated the pest by figures.

In 1921, Essig recommended clean culture, winter flooding, and crop rotation for the control of the "garden symphylid" in asparagus and truck crop regions.

Wymore, in 1924, discussed the "garden centipede" as a pest in asparagus regions of California and recommended flooding as the most efficient method of control. Of the chemical fumigants tried, "paradichlorobenzene proved very effective in a single instance as a control for this pest."

The writer, in 1928, pointed out the importance of *Scutigerella immaculata* Newp. as a pest in vegetable, as well as in ornamental, greenhouses. Lettuce, cucumbers, tomatoes, and sweet peas were especially seriously damaged. Two species of true centipedes, *Lithobius forficatus* Linn. and *Lithobius bilabiatus* Wood, were reported as predaceous on the garden symphylid. Various control measures were discussed.

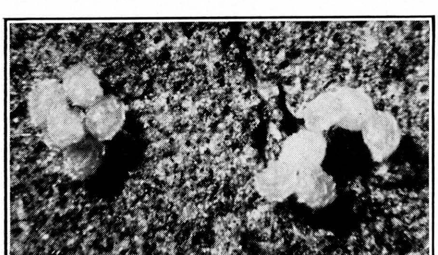

**Fig. 1.—Eggs of the garden symphylid. x10**

## DESCRIPTION

**Egg.**—The egg of the garden symphylid is a tiny spherical body about ½ millimeter in diameter. It is pearly white and is decorated with a network of ridges. The ridges divide the chorion into more or less hexagonal areas. These spaces are further marked with secondary ridges. Eggs are usually laid in clusters consisting of from 4 to 25 eggs. Single eggs are also found in infested soil and are very common in rearing cages. A few days after the eggs have been laid they become a dingy white color. (Fig. 1.)

**Larva.**—The young larva escapes from the egg through a narrow, elongate opening in the chorion. One end of the larva, usually the anterior, is freed first, and this portion writhes from side to side and up and down with frequent pauses until the whole body is worked out of the egg. The short, five-jointed antennae are folded along the ventral side with the legs so that the young creature appears like a footless grub. A few minutes after hatching the antennae are moved forward and the legs are extended. The newly hatched *Scutigerella* is about 0.75 millimeter long, has ten dorsal scutes, and six pairs of legs. The first pair of legs are four-jointed and the rest are five-jointed. The posterior body segment bears a pair of tiny cerci, a pair of sensory stylets, and buds of a seventh pair of legs. The creatures molt in 24 to 36 hours and become much more active. They now have seven pairs of legs and eight to ten jointed antennae. The cerci are much longer and a thin web is secreted from each cercus. At each successive molt a pair of legs is added, also some antennal joints, until the creatures have 12 pairs of legs and 25 to 55 joints in the antennae (Fig. 2). Growth takes place by the interpolation of a body segment just in front of the last one. During the period when the creature is completing its growth, additional pairs of legs are added from time to time; likewise, dorsal scutes. By the time maturity is reached, six pairs of legs and four scutes will have been added. It was found that no scutes were added with the second and sixth molts in the few cases observed.

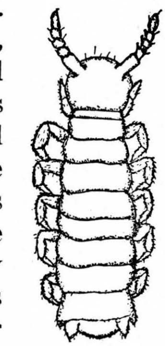

**Fig. 2.—Newly hatched garden symphylid. x40.**

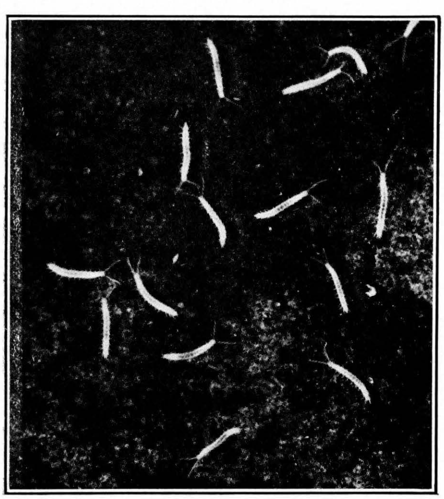

**Fig. 3.—Adult garden symphylids. Natural size**

**Adult.**—The adult garden symphylid is from 5 to 8 millimeters long and 0.3 to 0.8 millimeters wide. It is white, except where the dark-colored food may show through the body wall. Each segment, starting with the third, bears, in addition to the legs, a pair of stylets or parapods. At the base of each leg on these segments is a thin, membranous, coxal sac (Figs. 3 and 4).

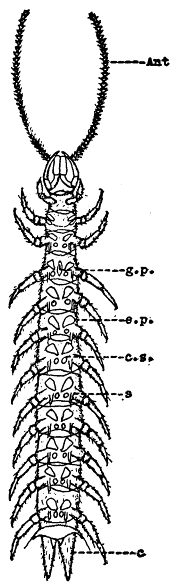


**Fig. 4.—Drawing of adult garden symphylid, ventral view. Ant., antenna; g. p., genital pore; e. p., episternal plate; c. s., coxal sac; s., stylus; c., cercus. x10.**

## MORPHOLOGY

A few morphological features that were studied will be briefly discussed.

### *ANTENNAE*

The antennae of the garden symphylid are very delicate, consisting of a series of bead-like segments. The writer found from 20 to 37 segments in the antennae, but Latzel found from 18 to 55. There are whorls of setae on each segment. The terminal segment bears a forked structure, which Hansen describes as a "striped organ".

### *MOUTH PARTS*

The mouth parts are of the chewing type. The mandibles are two-jointed. The distal edge is toothed with a rather deep incision in the middle of the cutting edge. In this incision is a small movable portion which is also serrated. The maxillae are rather long. The stipes and cardo are fused. A small, single-jointed projection is seen on each maxilla which is comparable to a palpus. The labium consists of two plates surrounded by membranes. The distal margin bears two pairs of small, notched lobes. (Fig. 5).

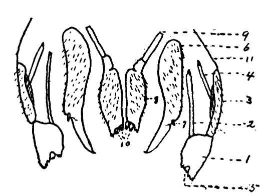

**Fig. 5.—Drawing of mouth parts of the adult. 1, distal segment of mandible; 2, muscle of distal segment; 3, proximal segment of mandible; 4, muscle of proximal segment; 5, movable tooth; 6, maxilla; 7, maxillary palpus; 8, labium; 9, basal joint of labium; 10, lobes of labium; 11, head capsule. x50.**

### *SEX CHARACTERS*

The males and females are very difficult to distinguish. In mature specimens the males are generally smaller than the females. The character which the writer found for distinguishing the sexes was the shape of the two small sternal plates between the third and fourth pairs of legs. These plates are

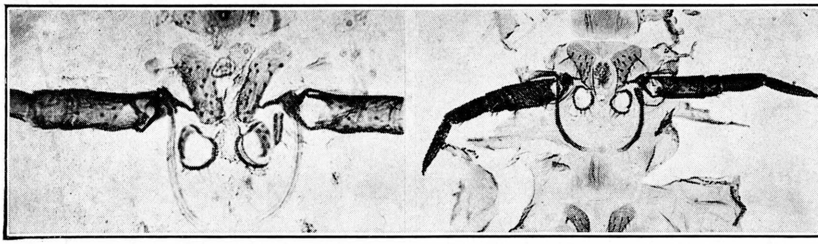

**Fig. 6.—Photograph of sternal plates of the adult, showing shape of the plates which surround the genital pore. Male, left; female, right. x75**

located on each side of the genital pore. The sternal plates of the male are elongate, somewhat rectangular, and blunt-ended. The two plates are placed in the form of a V with the small genital pore situated on the median line, just behind the point where the blunt ends of the plates approach each other. The plates of the female are triangular and are "hollowed out" near the median line. These hollowed out portions surround the elongate genital pore. (Figs. 6 and 7).

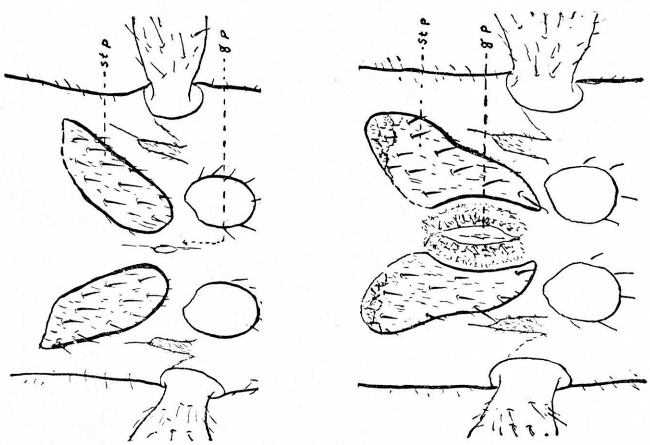


**Fig. 7.—Drawing of the sternal plates, fourth segment of the adult. Male, left; female, right. g. p., genital pore; st. p., sternal plate. x200**

The ovaries of the female consist of a pair of elongate tubes which extend back from the genital pore, lying just above the nerve cord and beneath the digestive tract. When the ovaries are filled with eggs, the digestive tract is crowded aside or even beneath the ovaries. The testes of the male occupy a position similar to that of the ovaries in the female. They consist of paired, very thin, granular structures somewhat coiled and extending posteriorly to approximately the ninth body segment.

### *DIGESTIVE SYSTEM*

The digestive apparatus consists of a simple canal extending from the mouth to the anus. The esophagus is occasionally curved in a sort of S-shape, probably to allow for the elongation of the body without stretching the digestive tract. The mid-intestine is comparatively large and long. The hind-intestine is more slender. At the junction of the mid- and hind-intestine are connected two Malpighian tubes. These extend forward along the mid-intestine and are approximately equal to it in length.

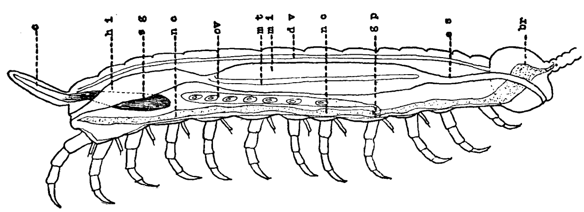

**Fig. 8.—Drawing of cross-section through adult. c., cercus; h. i., hind-intestine; s. g., silk gland; n. c., nerve cord; ov., ovary; m. t., Malpighian tube; m. i., mid-intestine; d. v., dorsal vessel; g. p., genital pore; es., esophagus; br., brain. x10.**

The dorsal vessel is a very thin-walled, slender tube extending the entire length of the body.

The nervous system consists of a large cephalic lobe or "brain" and a ventral nerve cord with slight ganglion-like enlargements for each somite where tiny branches enter the legs. (Fig. 8).

A large silk gland is attached to each cercus and extends into the body as far as the ninth segment. Figure 8 gives a general idea of how the various organs are arranged in the mature female.

The tracheal system is located in the anterior part of the body. There is a tiny spiracle on each side of the head below the antenna. These open into tracheal tubes which branch and rebranch into very minute tubes extending back through the second body somite.

### TECHNIQUE

The morphology was studied from live material, from dissected material, and from prepared slides. The following are the steps in the technique of preparing slides:

**Making whole mounts of symphylids.**—Fresh, live material is best for making whole mounts of Symphylids for the study of the internal organs through the body wall.

1. Kill creatures in hot water. (80°-90° C.)
2. Fix for 24 hours or longer in Gilson's Fluid:

| | |
|---|---|
| Mercuric chloride | 5 gm. |
| Glacial acetic acid | 1 cc. |
| Nitric acid (Sp. gr. 1.456, 8%) | 3.75 cc. |
| Alcohol 95% | 15 cc. |
| Distilled water | 230 cc. |

3. Wash in at least two changes of 70% alcohol. Straighten all curved specimens.
4. Stain in Borax Carmine 24 hours or longer. (Until creatures are dark red.) It may be necessary to puncture body wall with a very fine needle to allow penetration of stain.
5. Differentiate in acidulated alcohol. (100 cc. 70% alcohol plus 1 cc. HCl). Sufficient acid is added to complete differentiation of exoskeleton to light pink in 5 to 6 hours. This leaves the internal organs darker.
6. Change to 90% alcohol, 12-24 hours.
7. Change to absolute alcohol, 12-24 hours.
8. Change to Benzol or Xylol, 24 hours.
9. Place on slides in Canada Balsam.
   Cover glass should be slightly narrower than slide to permit sealing if necessary.

**Preparing symphylids for sectioning.**—Always use fresh, live material for sectioning.

1. Kill creatures in hot water. (80°-90° C.)
2. Fix in Gilson's Fluid for 24 hours.
3. Place in 70% alcohol for 24 hours. Straighten all curved specimens.
4. Change to 80% alcohol, 12-24 hours.
5. Change to 90% alcohol, 12-24 hours.
6. Change to absolute alcohol.
7. Change to absolute alcohol plus Xylol, 2-4 hours.
8. Change to Xylol, 24 hours.
9. Change to Xylol-paraffin paste.
10. Imbed in paraffin.
11. Section.
12. Place on slides. Slides are first covered with an egg albumen solution prepared by adding enough powdered, dry, egg albumen to make the water very slightly milky. Ribbons are placed on top of the wet slides and these put on a warm plate in order to straighten the ribbons. Enough water is kept under the ribbons to keep them from sticking to the slide until flattened. Allow ribbons to dry.

13. Dissolve paraffin in Xylol.
14. Wash in 95% alcohol, 5 minutes.
15. Wash in water for 3 minutes.
16. Stain in Delafield's haematoxylin, 30 seconds.
17. Wash in water and examine under microscope. Nuclei should be stained blue while cytoplasm is practically unstained.
18. Counterstain in eosin for 2 minutes.
19. Wash in 95% alcohol.
20. Cover with Euparal and cover glass.

The technique of Haase was used in studying the tracheal system. The stomatal openings can be demonstrated by submerging live creatures in glycerine and observing the bubbles coming from the openings. The course of the tracheae can be traced by dipping live creatures (preferably young ones) momentarily into 95% alcohol and enclosing them in glycerine under a cover glass. The animals become clear and the tracheae appear black in transmitted light and silvery in reflected light, due to the enclosed air. The observations must be made within a few hours after preparation, as the air soon leaves the tracheae and glycerine enters. Haase also suggested placing the creatures in a .2% osmic acid for 24 hours. A dark precipitate is formed in the tracheae.

## GEOGRAPHIC DISTRIBUTION

**Scutigerella immaculata** Newport is quite generally distributed throughout the world. Hansen (1903) states that "the species is evidently common from the southern part of Sweden through the whole of Europe to Algeria". It is known in Sweden, Russia, Denmark, England, France, Germany, Austria, Czecho-Slovakia, Hungary, and Italy. It has been found in Algeria in Africa and in Buenos Aires and Argentina in South America. Packard (1881) states that he examined specimens from Mexico. In the United States, the garden symphylid has been reported from California, Colorado, Georgia, Illinois, Indiana, Kansas, Kentucky, Massachusetts, Michigan, New York, Ohio, Oregon, Pennsylvania, Texas, and Utah. In Ohio, specimens have been collected by the writer in Cincinnati, Columbus, Mt. Healthy, Piqua, Sidney, and Xenia, and Williams and Hefner (1928) report collecting the species in Oxford and Put-in-Bay. Williams informed the writer that he also collected some specimens of this species in an undisturbed forest near Bowling Green, Ohio.

## METHODS OF DISPERSAL

Since the creatures are found in moist soil along streams, they can easily be carried with such soil from one place to another. The exchange of plants among growers may be a means of spreading the garden symphylids, especially if soil is left on the roots. Manure is often stacked outside of greenhouses and along truck fields and becomes infested. The symphylids are then taken wherever the rotted manure is used. In some cases, the creatures have migrated into greenhouses from adjoining fields; they follow earthworm burrows and can easily get under greenhouse foundations where these are not deeply set.

## HOST PLANTS

The garden symphylid is a very general feeder. Within the writer's experience, lettuce, cucumbers, tomatoes, radishes, parsley, spinach, snapdragons, sweet peas, calendulas, chrysanthemums, stevia, freesias, and smilax, grown under glass, were found injured by the pest. Outside crops, such as celery, carrots, eggplant, beets, and asparagus, growing in the vicinity of the greenhouses, have also been damaged, occasionally amounting to a total loss. Many of the common weeds and grasses were also destroyed by the symphylids. One truck crop grower told the writer that in his experience the garden symphylid fed on all the crops he tried to grow with the exception of onions.

## LIFE HISTORY AND HABITS

The garden symphylid is primarily terrestrial in habits. In greenhouses, it lives in earthworm burrows, in natural crevices in the soil, in openings left by decaying roots, etc. The eggs are laid in the runways in clusters of from 4 to 25. Williams (1907) states that the females guard the eggs until hatched. The writer has not observed females guarding eggs in greenhouse soil, although females are often present where eggs are found. Most of the eggs are laid during the spring and early summer, but eggs have been collected in December in greenhouses so that under these conditions egg-laying apparently continues throughout the entire year. Eggs hatch in an average of 10.8 days at approximately 70° F. The shortest time observed was 7 days and the longest, 20 days; these figures are based on 196 eggs reared in the laboratory at room temperatures. The newly hatched larvae are rather hairy creatures and move about quite slowly, usually remaining near the eggshells.

The first molt takes place in one to 4 days, usually within 24 to 36 hours. The creatures then become much more active and closely resemble the adults. A peculiar fact about garden symphylids is that they continue to molt at intervals throughout their lives; one female molted 6 times after laying eggs, indicating that sexually mature creatures continue to molt. The periods between molts vary considerably; the first molt occurs usually within 36 hours after hatching; the next five molts occur on an average of 8 days apart, the shortest period recorded being 3 days and the longest 34 days. As the symphylids become older, the molts are less frequent, occasionally several months apart. Individuals have been kept in a laboratory for 2 years and 4 months, which seems to be unusually long for such frail creatures. From 40 to 60 days at room temperature are required for a garden symphylid to become sexually mature.

The garden symphylids have a peculiar habit of migrating to the subsoil, under greenhouse conditions, with the approach of warm weather in the spring. The optimum temperature was found to be 65° F. When the soil temperatures reach 70°-75° F. at the surface, the creatures follow their runways to the subsoil 24 to 36 inches below and there spend the summer. In the fall when the weather becomes cooler and the soil is watered preparatory to fall planting, the symphylids again migrate to the surface. As soon as the plants are started the creatures begin feeding on the roots. They are not able to make their own burrows for migrating through the soil but, as has been stated, depend upon other agencies for passageways. These runways are lined with a light webbing and the creatures, as they move about, seem to "feel" their way along these webs with their antennae.

The following experiment demonstrated the inability of the symphylids to make their own burrows through soil. Two stender dishes were half filled with moist, loam soil and the soil tamped sufficiently to close all larger interspaces and to make a smooth surface. Five garden symphylids were then put in each dish. Two small earthworms were also put into one of the dishes. Lettuce leaves were placed on the surface of the soil for food. In 6 months four of the symphylids in the dish without earthworms were still on the surface. (One died during this time). The second day all the symphylids in the dish with earthworms had followed the earthworm burrows into the soil.

## METHODS OF REARING

Rearing of garden symphylids was done in stender dishes into which was poured a "muck plate", made by mixing ten parts of plaster of Paris and three parts of finely ground muck. This muck plate was kept moist and the symphylids lived on the surface. Lettuce leaves were laid on the surface of the plate for food and to afford hiding places. Where large dishes were used and large portions of leaves introduced, it was necessary to make grooves in the muck plate to give the symphylids a chance to escape from the weight of the leaf and from being caught and smothered when the leaf decomposed and lay flat on the surface of the plate. The dishes were kept in a dark compartment as shown in Figure 9.

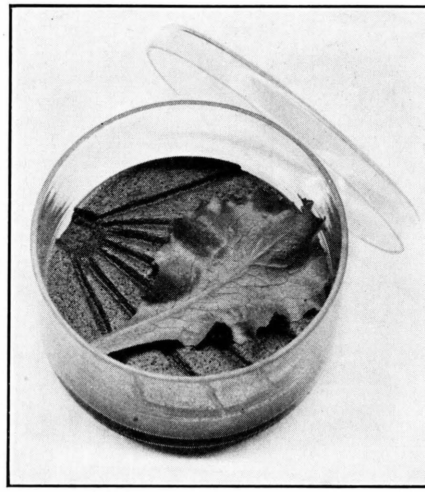

**Fig. 9.—Dish with muck plate in bottom, used in rearing garden symphylid**

## NATURE OF INJURY AND ECONOMIC IMPORTANCE

Injury to greenhouse crops is done to the underground portion of the plant and to parts in contact with the soil. The creatures destroy the fine root hairs and small rootlets, thus stunting the plants and often killing them outright. The stunted plants are very slow to mature and represent a loss to the grower (Fig. 10). Small depressions are often gouged out in the crown of some plants and small holes are drilled into such rootplants as radishes, beets, and carrots. The rootplants often develop more than one main root, following an early injury to the tap-root. Warty, corky growths occasionally appear on beets and carrots where holes had been drilled some time before. Where plant leaves happen to touch the ground, they are riddled with holes. Such crops as asparagus and celery are ruined for the market because of the damage to the plants due to holes in the stalks and to the rusty, corky growths which often develop.

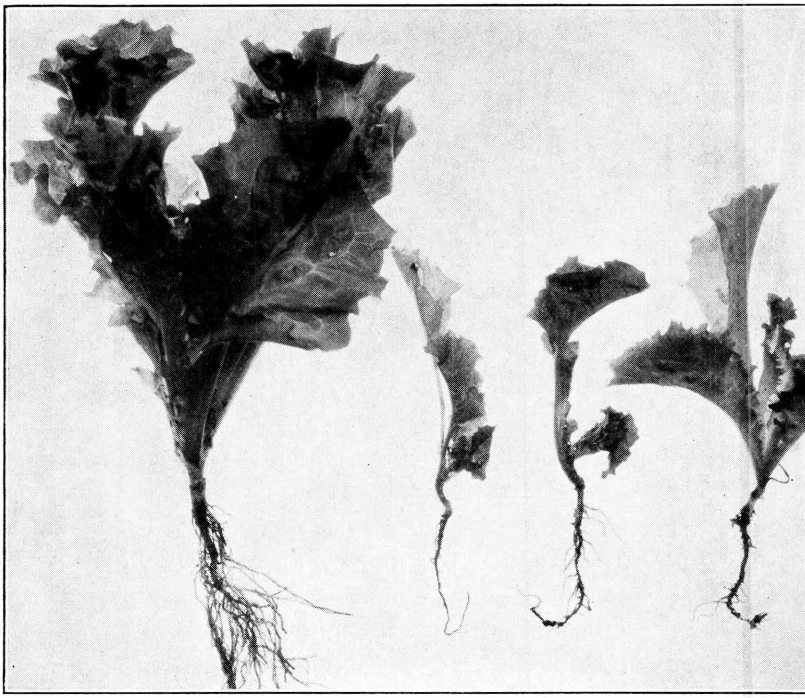

**Fig. 10.—Lettuce plant on left normal. Three plants on right injured by garden symphylids. Note scarcity of roots on injured plants**

The financial loss to greenhouse men and to truck crop growers in the infested areas has been enormous during the last few years. Several greenhouse men in southwestern Ohio have stated to the writer that they had been unable to grow a paying crop for several years, due to the garden symphylid (Fig. 11). Some valuable truck land has been lying idle because it has not paid the growers to plant crops in infested fields. Some growers who did not understand the nature of the injury simply called their land "crop sick" and changed to new locations. Wymore (1924) reports that thousands of acres of asparagus are damaged annually in California.

In greenhouses, damage first occurs along the walls, paths, and purlins where the soil is but little disturbed by cultivation. Such places have unbroken burrows which harbor the garden symphylids (Figs. 11 and 12).

Fig. 11.—Lettuce crop destroyed by garden symphylids

Fig. 12.—Lettuce destroyed along walks and purlins

## CONTROL

A long series of experiments has been conducted by the writer during the last few years in an attempt to find some means of combating the garden symphylid in the greenhouses of southwestern Ohio. This pest presents a peculiar problem in that the actual control data, as indicated by the numbers of dead or living animals following a given treatment, are very difficult to obtain. The symphylid is so delicate that when the investigator digs into the soil to make counts many are crushed and are thus difficult to find. Dead individuals decompose so rapidly that in a short time it is impossible to distinguish the dead bodies from cast skins. In one series of experiments where growing crops were treated and counts were possible within 24 hours, such records were taken. In all other cases, it was found that the best measure of the success of a treatment was the condition and the yield of the crop that followed.

A discussion of the control experiments, the methods employed, and the results obtained can conveniently be divided into two groups. In the first group, treatments were applied before the crops were planted, and in the second, treatments were applied to the growing crop. Table 1 summarizes the first group and Table 2 summarizes the second group.

### *TREATMENTS BEFORE CROPS ARE PLANTED*

**Steam sterilization.**—Three methods of steam sterilization were tried; namely, the "buried tile", "pan", and "harrow" methods.

The buried tile method of steam sterilization was the only one that proved successful in controlling the garden symphylid. For this method of sterilization, the beds are tiled with 3- or 4-inch, porous, drainage tiles laid 18 to 24 inches apart and about 12 inches below the surface of the soil. The length of tile lines and the number of lines connected to a header depend upon the capacity of the boiler that furnishes steam. For thorough sterilization a unit horsepower of boiler capacity is required for every 6 to 10 square feet of bed surface. (Fig. 13).

Since the garden symphylid has the habit of going down into the subsoil during the summer, sterilization must be done during the fall or winter when the creatures are occupying the soil strata above the tiles. A good plan is to spade up and moisten the soil before planting in the fall. The water will cool the soil and the spading will make it better fit for sterilization. For the purpose of helping attract the creatures to the surface, some lettuce seed is then scattered over the bed and allowed to germinate. When the symphylids are found feeding on the plant roots, sterilize thoroughly, heating an entire bed at the same time, if possible. All paths should be spaded and sterilized, also, to destroy any symphylids that may be hiding in the undisturbed soil. If the beds are covered with tough mulching paper, the steam will be confined to the soil and a more thorough sterilization effected. The heating should continue from 2 to 8 hours or more, depending upon the type

**Fig. 13.—Lettuce grown on soil sterilized with steam, tile method. Previous crop destroyed**

and condition of the soil and upon the steam pressure. The process will not only control the symphylid but will also control nematodes and soil-borne diseases. Some disease organisms have been known to live through 8 hours of steaming. In other words, sterilization of sufficient intensity to control plant diseases is certain to be effective against the garden symphylid. Reference to Table 1 will show that in each case where tile steam sterilization was tried the yield of the crop following was very materially increased.

The pan and harrow systems of steam sterilization were not effective in controlling the garden symphylid. The heating of the soil from the surface by either the pan or harrow methods apparently influences the symphylids much as does the spring heat and simply drives them down into the subsoil. As soon as the soil cools they return to the upper soil strata. (Fig. 14).

**TABLE 1.—Results of Various Control Treatments Applied Before Crops Were Planted**

| Expt. No. | Treatment | Size of plot | Crop | Results |
|---|---|---|---|---|
| 1<br>1a | Steaming—tile method..........<br>Check .......................... | 75 ft. x 12 ft.<br>75 ft. x 12 ft. | Lettuce<br>Lettuce | 135 ten-pound baskets<br>39 ten-pound baskets |
| 2 | Steaming—tile method.......... | 100 ft. x 12 ft. | Lettuce | 258 ten-pound baskets<br>No check. Previous crop destroyed |
| 3 | Steaming—tile method.......... | 200 ft. x 24 ft. | Lettuce | 552 ten-pound baskets<br>No check. Previous crop severely damaged |
| 4<br>4a | Steaming—pan method .........<br>Check .......................... | 50 ft. x 12 ft.<br>50 ft. x 12 ft. | Lettuce<br>Lettuce | Destroyed by symphylids<br>Destroyed by symphylids |
| 5<br>5a | Steaming—harrow method......<br>Check .......................... | 75 ft. x 8 ft.<br>75 ft. x 8 ft. | Lettuce<br>Lettuce | Destroyed by symphylids<br>Destroyed by symphylids |
| 6<br>6a | Raised bench....................<br>Check (ground bed)............ | 75 ft. x 6 ft.<br>75 ft. x 6 ft. | Snapdragons<br>Snapdragons | No symphylids<br>Severely damaged by symphylids |
| 7<br>7a | Carbon bisulfide emulsion.......<br>Check .......................... | 75 ft. x 8 ft.<br>75 ft. x 8 ft. | Lettuce<br>Lettuce | Severely damaged by symphylids<br>Severely damaged by symphylids |
| 8<br>8a | Paradichlorobenzene—1½ lb. per 100 sq. ft. under manure...<br>Check .......................... | 75 ft. x 12 ft.<br>75 ft. x 12 ft. | Lettuce<br>Lettuce | 117 ten-pound baskets<br>50 ten-pound baskets |
| 9<br>9a | Paradichlorobenzene—1 lb. per 100 sq. ft. under manure ......<br>Check .......................... | 175 ft. x 12 ft.<br>175 ft. x 12 ft. | Lettuce<br>Lettuce | 200 ten-pound baskets<br>Destroyed by symphylids |
| 10<br>10a | Paradichlorobenzene—no manure ......................<br>Check .......................... | 150 ft. x 12 ft.<br>150 ft. x 12 ft. | Lettuce<br>Lettuce | 160 ten-pound baskets<br>75 ten-pound baskets |
| 11<br>11a | Paradichlorobenzene—1½ lb. per 100 sq .ft. on top of manure<br>Check .......................... | 75 ft. x 8 ft.<br>75 ft. x 8 ft. | Lettuce<br>Lettuce | 81 ten-pound baskets<br>39 ten-pound baskets |
| 12 | Paradichlorobenzene—1 lb. per 100 sq. ft. No manure ........ | 75 ft. x 8 ft. | Lettuce | 500% to 600% increase over previous crop (Grower's statement) |
| 13<br>13a | Carbon bisulfide—1 oz. per sq. ft. on subsoil..................<br>Check .......................... | 75 ft. x 8 ft.<br>75 ft. x 8 ft. | Lettuce<br>Lettuce | Approximately 75 ten-pound baskets<br>Destroyed by symphylids |
| 14<br>14a | Calcium cyanide—1 lb. per 75 sq. ft..........................<br>Check .......................... | 75 ft. x 5 ft.<br>75 ft. x 5 ft. | Lettuce<br>Lettuce | Approximately 75 ten-pound baskets<br>Destroyed by symphylids |

**Fig. 14.—Lettuce grown on soil sterilized with steam, pan method. Note unsatisfactory result**

**Raised benches.**—Many flowers and some vegetables can be grown successfully in raised benches. Where this system is practical it will solve the symphylid problem. Thoroughly working the soil before putting it into the raised bench will kill most of the symphylids and reinfestation is not possible, because the connection with the subsoil which harbors the pest is broken. As has been previously stated, it seems that the subsoil is a necessary hiding place for the creatures during the summer and affords a breeding place for them.

**Soil fumigation.**—Where steam was not available, several soil fumigants were tried. Chemicals which have proved effective in controlling the garden symphylid are paradichlorobenzene, carbon bisulfide, and calcium cyanide.

Many growers in southwestern Ohio practice what they term "making up" their soil. This consists in removing the surface soil to a depth of 6 to 8 inches. They then place a layer of manure on the subsoil and replace the surface soil on top of the manure. This gave the writer an opportunity to try some soil fumigants put on the subsoil without additional labor, except that of distributing the materials. Time and labor were saved in applying the material by starting at one end of the bed and removing a strip of the surface soil about 4 feet wide across the bed and then treating the exposed subsoil. Next, the surface soil from an adjoining strip of similar size was shoveled onto the subsoil just treated. This process exposed a new area of subsoil, which in turn was treated, and so on through the bed. (Fig. 15).

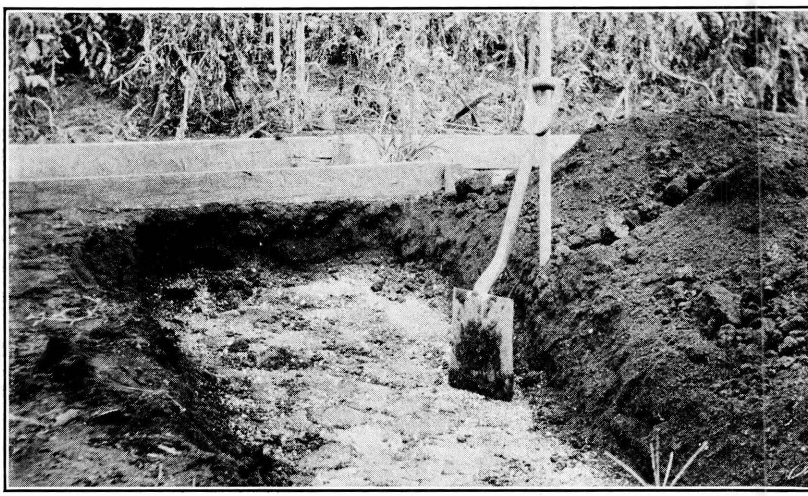

**Fig. 15.—Method of applying soil fumigants to subsoil**

For best results, the soil should be in good working tilth; if too wet, inadequate penetration may result, and, if too dry, the fumigant may escape through the upper layers.

Paradichlorobenzene gave best results when applied at the rate of 1 pound per 100 square feet. Larger amounts stunted the crops which followed the treatment. It is of particular importance that adequate time elapse following the application of paradichlorobenzene to allow the fumes to disperse. It is difficult to state definitely how much time should elapse, since much depends upon the texture and condition of the soil; under average conditions about 3 weeks should be sufficient. (Fig. 16).

Carbon bisulfide proved very satisfactory in controlling the garden symphylid, when applied during the "making up" process. It was sprinkled on the subsoil at the rate of 1 ounce per square foot and covered as quickly as possible to prevent the escape of poisonous gases. While working with carbon bisulfide, all ventilators of the greenhouse should be open and great care should be exercised to

**Fig. 16.—Lettuce crop produced after treating subsoil with paradichlorobenzene for control of garden symphylids**

keep fire away, since the fumes of the material are highly inflammable. Where "making up" is not practiced, carbon bisulfide may be applied to the bed by making holes about 15 inches deep and 1½ inches in diameter, 12 inches apart each way and by pouring an ounce of the material into each hole and covering it with soil.

Calcium cyanide was scattered on the subsoil at the rate of 1 pound to 75 square feet of surface and covered quickly. This material was very effective in controlling the garden symphylid and did not stunt plants, even if applied only a short time before planting. (Fig. 17).

Fumigants applied to the subsoil should be used during the summer or early fall while the symphylids are still in the lower soil strata. In this way the poisonous gases produced will have an opportunity to penetrate the openings in the subsoil and kill the creatures.

Carbon bisulfide emulsion, when used as a surface application, failed to control the garden symphylid. It was prepared by dissolving 5 pounds of fish oil soap in 3 gallons of water; to this were added 6 gallons of carbon bisulfide, and the mixture was emulsified with a bucket pump until it became a creamy emulsion. This stock solution was tried in three strengths: 1 quart to 50 gallons, 2

Fig. 17.—Lettuce crop produced after treating subsoil with carbon bisulfide for control of garden symphylids

quarts to 50 gallons, and 3 quarts to 50 gallons of water. The dilute mixtures were poured over the soil at the rate of ½ gallon to each square foot of surface. For a short time following treatment the plants grew vigorously, indicating that some of the symphylids had been killed, but before the crop was mature other symphylids came up from the subsoil and destroyed the plants.

### *TREATMENTS AFTER CROPS ARE PLANTED*

**Soil fumigation.**—Occasionally, infestations of the garden symphylid develop in considerable proportions before the grower is aware that the pest is present. Beds may be planted and crops partly grown before the damage is discovered. A few such beds were treated by the writer to determine if the creatures could be controlled without destroying the growing crop. Carbon bisulfide was used as a soil fumigant in these experiments. In one case, this material was placed in a steel drum and volatilized with steam and the steam, together with the volatilized carbon bisulfide, was forced into tiles with which the bed was equipped. Steam at low pressure entered the drum at the top through a small hole, and connection into the tiles was made from the middle of the drum through a large opening. Approximately a pound of carbon bisulfide was volatilized for every 50 square feet of bed. Steaming continued for 15 minutes, at the end of which time all the carbon bisulfide had been volatilized. Counts made the next day showed that only about one-half of the symphylids were dead. The material penetrated the soil very unevenly. In patches the control was excellent; whereas in other places the kill was very poor. A dosage of an ounce per square foot no doubt would have given better control. This method should give good results where the soil is uniform.

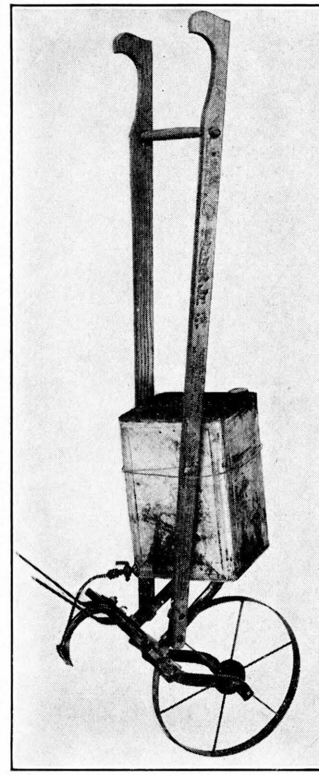

**Fig. 18.—Apparatus for applying carbon bisulfide in soil along rows of growing plants.**

Carbon bisulfide proved very effective in controlling the symphylids when "drilled" on both sides of plant rows at the rate of 4 pounds to 150 feet of row. The material should be drilled about 4 inches from the base of plants and about 2½ inches below the surface of the ground. If drilled too close to the plants, temporary wilting, or even permanent injury, may result. The apparatus used in applying the material consisted of a 5-gallon can mounted on the handles of a common wheel hoe. A copper tube was soldered into the lower corner of the 5-gallon can and was so shaped that it terminated below a small cultivating shovel. A stop-cock in the line regulated the flow of carbon bisulfide. The apparatus is illustrated in Figure 18.

**TABLE 2.—Results of Control Measures Applied to Growing Sweet Peas**

| Plot No. | Treatment | Per cent control |
|---|---|---|
| 1 | Steam and carbon bisulfide | 52% of symphylids were dead |
| 2 | $CS_2$, 4 lb. to 100 ft. of plant row. 3 in. from base of plants | 100% of symphylids were dead |
| 3 | $CS_2$, 4 lb. to 150 ft. of plant row. 4 in. from base of plants | 100% of symphylids were dead |
| 4 | $CS_2$, 4 lb. to 150 ft. of plant row. 5 in. from base of plants | About 90% of symphylids were dead |
| 5 | $CS_2$, 4 lb. to 150 ft. of plant row. 6 in. from base of plants | About 50% of symphylids were dead |

Carbon bisulfide can also be applied to beds of growing plants by pouring it into holes made by forcing a pointed instrument into the soil to a depth of 15 inches. The holes should be spaced a foot apart along both sides of each row and about 4 or 5 inches from the base of the plants. An ounce of the material should be poured into each hole.

## *SUPPLEMENTARY CONTROL MEASURES*

In addition to the experiments previously discussed, observations were made on various practices which have proved beneficial in keeping the symphylids in check. Thoroughly working an infested soil during the interval between crops when the symphylids are still near the surface always checks the activity of the creatures, as many are killed by this process. Moreover, the burrows and passageways are broken, thus decreasing the possibility of the symphylids reaching plant roots. When plants are first set out into infested beds, they should be watered lightly. If beds are soaked heavily, earthworms and other soil inhabiting animals will come to the surface, leaving burrows for the symphylids to follow. Watering may be increased after the plants have become established.

Heavy applications of manure or other organic matter render the soil very porous and should be avoided on infested beds, as it makes conditions ideal for the symphylids. If fertilization is necessary, commercial fertilizers should be used in infested houses. Since garden symphylids are spread with soil, in rotted manure, and on plant roots, great care should be exercised to prevent the introduction of the creatures into uninfested houses by these means. Soil and manure should be carefully examined before being taken into greenhouses. If it is necessary to use plants from infested houses, wash all the soil from the roots and pack the plants in moist sphagnum moss for transportation.

In the discussion dealing with geographic distribution it will be noted that, in Ohio, garden symphylids have not been reported from greenhouses north of Columbus and Sidney. There seems to be no reason why the creatures should not become a serious pest in the northern part of the State, once they were introduced. For this reason, every precaution should be taken to prevent the spread of the symphylids to new territory. The acreage under glass and in truck crops is even greater in the northern part of the State than in the southern part.

## *BIOLOGICAL OR NATURAL CONTROL*

There are at least two species of true centipedes which are predacious on the garden symphylid. One species, *Lithobius forficatus* Linn., is a dark brown creature about an inch long. Both the adults and the young of this species have been observed to eat garden symphylids. One *L. forficatus*, a week old, devoured 6 individuals in one night. The other species, *Lithobius bilabiatus* Wood, is a much smaller, light brown centipede and is often mistaken for the garden symphylid. This species is able to enter the runways of the garden symphylid, even in the adult stage. The writer had occasion to visit a greenhouse where the predacious centipedes were quite numerous and, no doubt, were responsible to a great extent for the control of the garden symphylids which had ruined crops in this house for several years before the predaceous forms became abundant (Fig. 19).

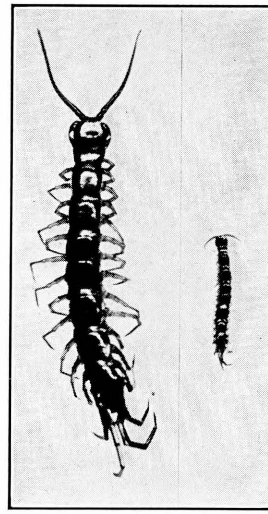

**Fig. 19.—Beneficial, predaceous centipedes which destroy the garden symphylids. Large,** *Lithobius forficatus*; **small,** *Lithobius bilabiatus*. **x2½ (approx.).**

Since the garden symphylids are unable to make their own burrows through the soil, the destruction of such burrowing forms as earthworms and millipedes would aid in controlling them, as they would find it more difficult to get to plant roots.

### CONTROL OUT-OF-DOORS

Very little has been done in Ohio in working out control measures for the garden symphylid in truck fields. One grower reports some benefit from carbon bisulfide when drilled into the soil just before planting in late spring. The apparatus he used was much like the one illustrated in Figure 18. He drilled the material in rows about a foot apart one way and then crossed these rows at right angles again about a foot apart. He regulated the flow of the material so that about an ounce per square foot was applied. The material was drilled about 3 inches below the surface of the soil.

Wymore (1924) tried several measures for the control of this pest in asparagus fields in California. He found that "paradichlorobenzene proved very efficient in killing the animals when one ounce of the material to 3 linear feet was scattered along on both sides of the asparagus row. This experiment was conducted during the latter part of May when there was yet considerable moisture in the soil. Later experiments, when the soil had become drier, were not nearly so efficient." Wymore concludes that "flooding has proven the most efficient and satisfactory control measure for the garden centipede." He writes, "It was found that where the soil in certain portions of the field was not kept continuously covered to a depth of at least six inches, many garden centipedes remained alive. Where the soil was sufficiently covered most of the little animals were dead by the end of the first week and at the end of ten days not a single live one could be found." It appears to the writer that under Ohio conditions such flooding would be very difficult where irrigation facilities are lacking.

## SUMMARY

1. The garden symphylid has within recent years become a pest of very great economic importance in Ohio in greenhouses and truck fields.

2. Injury to crops is done to the underground portions of plants and to parts coming in contact with the soil. Plants are stunted and may be killed outright.

3. The creatures are very frail; yet they may live for long periods. Individuals have been kept alive in the laboratory for 2 years and 4 months.

4. Garden symphylids under laboratory conditions require from 40 to 60 days to become sexually mature.

5. Unlike insects, these creatures continue to molt even after becoming sexually mature.

6. Sexes may be distinguished by the shape of the sternal plates of the fourth body segment.

7. The garden symphylid can be controlled in greenhouses by thorough steam sterilization using the tile method, if the creatures are in the upper soil strata when the work is done. Steaming in mid-summer when the symphylids are deep in the subsoil or at any season if the pan or harrow methods are employed will not give satisfactory results. In every instance observed where failure to control by steam sterilization has been reported, it has been found that either lack of thoroughness or improper timing of the work has been responsible.

8. Raised benches, where these are practical, have solved the symphylid problem.

9. Soil fumigants which have been found beneficial when put on the subsoil are paradichlorobenzene, calcium cyanide, and carbon bisulfide.

10. Paradichlorobenzene may stunt the first crop following its application, particularly if planting is done too soon after the treatment.

11. Some relief was obtained by drilling carbon bisulfide on both sides of rows 4 inches from the base of the plants.

12. Thoroughly working an infested soil between crops when the creatures are in the surface layers always checks their activity.

13. Careful watering at the time of planting is also beneficial in keeping the symphylids from plant roots.

14. Carbon bisulfide emulsion poured on the surface of the soil failed to control the garden symphylid.

15. The garden symphylid is spread by introduction of infested soil, infested manure, or on infested plant roots. It may also migrate into greenhouses under walls from adjoining fields.

16. In California, flooding is reported as being the only practical method of control under outdoor conditions.

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